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Research in Biotechnology and Environmental Science. 2022; 1(1): 12-15.

DOI: 10.58803/RBES.2022.1.1.03

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Research in Biotechnology and Environmental Science

Original Article

Biosorption of Boron from Industrial Wastewater by Green Algae *Spirogyra* sp.

Zeinab Salari[1], Zeynab Bayat[2], Shima Dabaghi[3,*], and Fatemeh Salahshoori Niaei[4]

[1] Department of Agricultural Biotechnology, Faculty of Agriculture, University of Shahid Bahonar, Kerman, Iran
[2] Department of Biology, Faculty of Sciences, Shahid Bahonar University of Kerman, Kerman, Iran
[3] Department of Chemical Engineering, Faculty of Engineering, University of Shahid Bahonar, Kerman, Iran
[4] Department of Biology, Faculty of Sciences, Naein Branch, Islamic Azad University, Isfahan, Iran

* ***Corresponding author:*** Shima Dabaghi, Department of Chemical Engineering, Faculty of Engineering, University of Shahid Bahonar, Kerman, Iran
Email: sh_dabaghi@eng.uk.ac.ir

ARTICLE INFO

Article History:
Received: 14/07/2022
Accepted: 27/08/2022

Keywords:
Algae biomass
Boron
Industrial wastewater
Spirogyra

ABSTRACT

Introduction: Increasing the concentration of Boron in drinking water, wastewater, and irrigation have negative effects on the human environment. This pollution can be partially removed by the application of phytoremediation technologies using algae or aquatic plants. The aim of the current study was to determine the biosorption capacity of the algae *Spirogyra* sp. for Boron from industrial wastewater and examine the best elimination conditions using different parameters.
Materials and Methods: In this study, 100 g of fresh algal biomass was collected from the industrial wastewater of a copper mine located in Kerman, Iran.
At first, algae was selected among various algal species concerning abundance and resistance ability to high concentrations of Boron. Then, removal of Boron by the algal was examined in terms of algae biomass levels (2 and 4 gr), incubation time intervals (2, 12. 24. 48, and 72 hours), and different concentrations of Boron (5, 10, 15, 25, and 100 ppm) on the were examined. The experiment was factorial with a completely randomized design framework and three replications.
Results: The results presented that the elimination of Boron from industrial wastewater was performed by biomass of algae *Spirogyra* sp. The maximum Boron absorption was achieved at concentrations of 5 ppm and an incubation time of 12 hours. The absorption of Boron was higher in 4 gr than in 2 gr of algae biomass treatment.
Conclusion: It can be concluded that algae *Spirogyra* sp. has a strong potential for boron removal in industrial wastewater containing boron ions.

1. Introduction

Boron is a paradoxical contaminant used for wastewater. From a health standpoint, it is a micronutrient for many plants and animals at low levels, while it is a poison at higher levels[1,2]. Exposure to large amounts of Boron (B) over short periods of time can affect the stomach, intestines, liver, kidney, and brain and can eventually lead to death[3]. The excessive amount of B in the cultivated soils can lead to B toxicity, and consequently inhibition of nitrate reduction and increased ammonium assimilation in tomato plants, accompanied by the loss of leaf biomass and disorders in organic nitrogen metabolism[4].

The WHO limit for Boron is set at 0.3 ppm for drinking water; however, there is some speculation that this limit can be increased to 2.4 ppm. Thus, it has been left to state and regional regulatory agencies to set limits on boron discharge in waste water[5]. Boron is diffused to the environment mainly in discharged industrial wastewater, including manufacturing facilities of heat-resistant materials, storage and distribution of solar energy systems, catalysts, ceramics, and glass[6]. Since B removal from industrial wastewaters has received interest among scholars, some methods, including adsorption–flocculation, electrocoagulation, reverse osmosis, precipitation, ion-exchange, use of B-selective resins, and some biological materials (such as duckweeds) have been tried[7-10]. Phytoremediation is defined as a process of decontaminating soil and aquatic systems by using plants, fungi, or algae to absorb heavy metals. Recently, aquatic plants, especially micro and macro algae, have received much attention as they can absorb metals and take up toxic elements from the environment or lessen their detrimental

► *Cite this paper as*: Salari Z, Bayat Z, Dabaghi Sh, Salahshoori Niaei F. Biosorption of Boron from Industrial Wastewater by Green Algae *Spirogyra* sp. Research in Biotechnology and Environmental Science. 2022; 1(1): 12-15. DOI: 10.58803/RBES.2022.1.1.03

effects[11,12]. The algae can be considered ideal candidates for the selective elimination and concentration of heavy metals due to its high tolerance to heavy metals, ability to grow both autotrophically and heterotrophically, large surface area/volume ratios, phototaxy, phytochelatin expression, and potential for genetic manipulation[13,14]. In recent years, several species of the algae, namely *Chlorophyta* and *Cyanophyta*, have been utilized to absorb and accumulate Arsenic and Boron ions from their environment into their bodies[15-17].

The current study aimed to determine the biosorption of capacity of the algae *Spirogyra* sp for B from industrial wastewater and examine the best elimination conditions using different parameters.

2. Materials and Methods

2.1. Collection of samples

To conduct the study, 100 g of fresh algal biomass was collected from the industrial wastewater of a copper mine located in Kerman, Iran. The collected samples were washed with distilled water to remove dirt and were passed from filter paper to reduce the water content. The biomass was then sun-dried for 4 days, followed by drying in an oven at 70°C for 24 hours, and finally crushed. The biomass was then sieved to reduce the size range of particles to 2-3 mm. In the next step, isolated samples were morphologically identified.

2.2. Biosorption studies

In order to study B removal capacity, the microalgal cells were performed at room temperature in 250 ml Erlenmeyer glass flasks containing an aqueous solution of B concentrations of 5, 10, 15, 25 and 100 mg/l, prepared using boric acid. Accurately weighed, 2 g and 4 g portions of biomass were added to each flask. The mixtures were agitated on a rotary shaker at 180 rpm for five contact periods of 2, 12, 24, 48, and 72 hours. The samples were centrifuged at 5000 rpm for 10 minutes. The remaining B concentration in the residual solution was analyzed by azomethine H spectrophotometric method. The experiments were conducted in triplicates, and the average values were considered [18,19].

All matrials were purchased from Merck co., Germany.

3. Results

In the study, the isolated and purified microalgal strains identified as *Navicula, cladophora*, *Spirogyra,* and *zygnema* by evaluating the morphological properties were used. Resistance of the isolated strains to high concentrations of B was determined. *Spirpgyra* had a higher resistance to B (1000ppm), compared to other algae, so it was selected for *further studies.*

Spirogyra is a genus of filamentous charophyte green algae of the order Zygnematales, named for the helical or spiral arrangement of the chloroplasts that is diagnostic of the genus (Figure 1)[20].

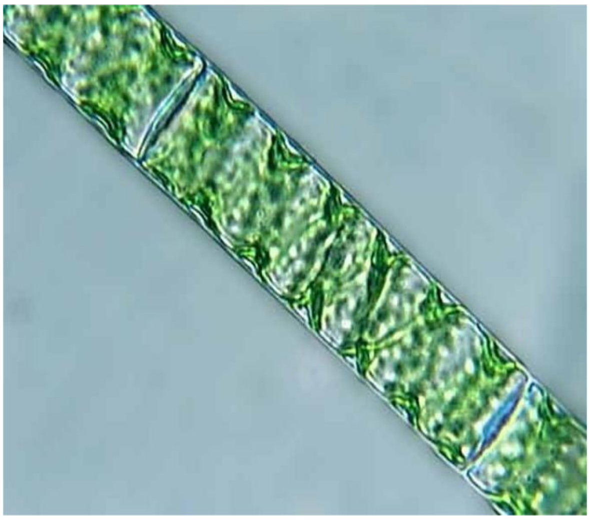

Figure 1. *Spirogyra*

3.1. Biomass concentrations

Figure 2 indicates the influence of microalgal biomass on B removal at five contact times. A decrease in the algal dose resulted in the decrease in B removal, indicating that a reduction of the algal dose led to a decrease in adsorption capacity. In other words, the absorption of Boron was higher in 4 gr of algae biomass treatment.

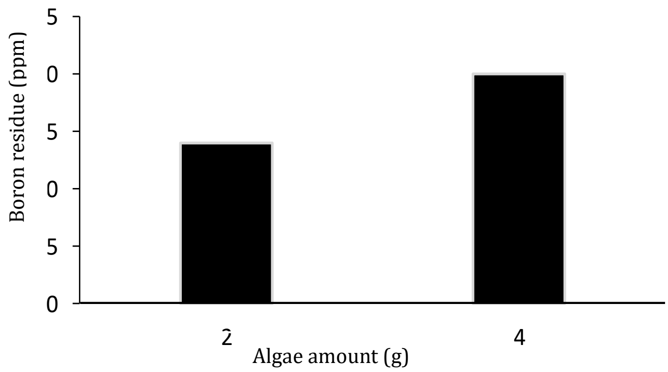

Figure 2. Effect of microalgal biomass on Boron removal

3.2. Contact times

Figure 3 shows the effect of contact time on the B removal at five different B concentrations. As can be seen, the minimum residual of B took place within 12 hours. The B uptake increased with the rise in contact time up to 12 hours and then remained almost constant.

3.3. Initial B concentration

Figure 4 shows the effects of different initial B ion concentrations on the B removal at two algal doses. The removal of B decreased when initial B concentrations increased up to 5mg/l.

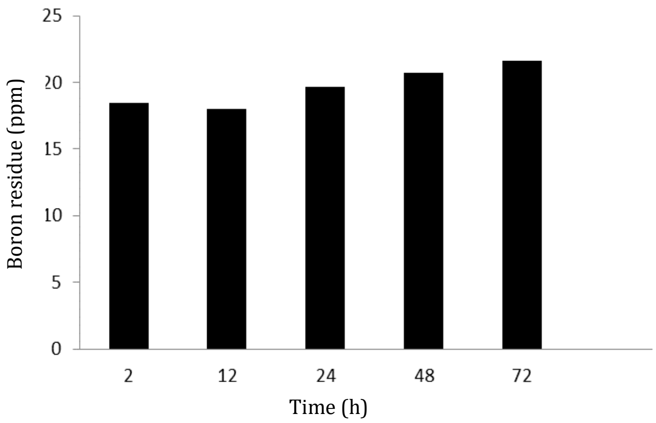

Figure 3. Effect of contact time on B removal

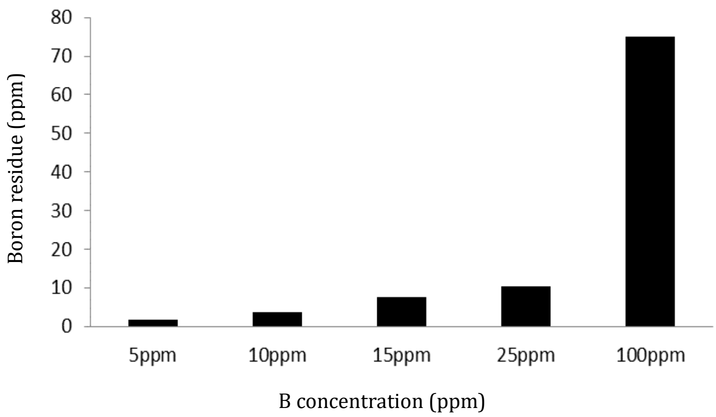

Figure 4. Effect of initial B concentration on B removal

4. Discussion

Phytoremediation of waters by algae has been recently reported[21]. The ability of algae to absorb metals has been recognized for many years. Algae can take up toxic elements from the environment, resulting in higher concentrations than those in the surrounding water [22, 23].

Two algae *Spiruline* and *Chlamydomonas* were reported for their ability to accumulate heavy metals, such as Zn, Pb, and Cu[24]. According to Baker et al., *Chlorophyta* and *Cyanophyta* are hyper-absorbents and hyper-accumulators for Arsenic and Boron, absorbing and accumulating these elements from their environment into their bodies. These algae can be hyper-phytoremediators, and their presence in water reduces water Arsenic and Boron pollutant[15].

The biosorption of heavy metals by algal species from aqueous solutions is a complex process, depending upon the algal species, the heavy metal ion, and the contributing source [26]. In the present study, *Spirpgyra* had a higher resistance to B (1000 ppm), compared to other algae.

In another study, the optimum conditions for the absorbent and adsorbate were Cr concentration of 5 mg/l in 120 minutes with an algal dose of 5 g/l. It was reported that with a decrease in algal dose for the same primary Cr concentration, adsorption capacity decreases, and with an increase in time, rate of percentage removal decreases. The maximum Cr removal levels were higher at higher biomass concentration[27]. The increase in the adsorption amount of solute is an obvious cause of increasing biomass surface area[28].

The results of the present study demonstrated that the B removal increased in initial B concentration. Similar results were found in another study indicating an increase in cobalt concentration resulted in the increase of Co^{2+} accumulation[28]. In fact, increasing initial Co^{2+} concentration significantly reduced algal growth.

Algal cells have revealed considerable potential in the elimination of heavy metal from aqueous solutions in previous studies[11,12]. Similar to present findings, Alpana et al observed 97% removal of Pb^{2+} by *Pithophora odeogonia* and 89% removal by *Spirogyra neglecta* in 30 minutes from a solution containing 5 mg/l primary concentration of Pb^{2+} by a biomass concentration of 1 g/l[29].

5. Conclusion

The obtained results of the current study indicated that algal biomass *Spirogyra* sp. have a higher tolerance and removal capacity than the other strains isolated from the polluted environment. The results also provided fundamental information in optimum algal dose, optimum contact time, optimum primary B ions concentration for maximum removal of B ions. The maximum B elimination was found at 4 g dry weight biomass in 12 hours with 5mg/l of initial concentration.

Therefore, it can be concluded that algal biomass *Spirogyra* sp. is a good adsorbing matrix for B and these algae can be the used for elimination of B from industrial wastewaters.

Declarations

Competing interests

The authors declare that there is no conflict of interest

Authors' contribution

All authors conceived and designed the study. All authors read and approved the final manuscript.

Funding

This research did not receive any specific grant.

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Ethical considerations

The authors checked for plagiarism and consented to the publishing of the article. The authors have also checked the article for data fabrication, double publication, and redundancy.

Acknowledgments

None.

References

1. Kabay N, Yilmaz I, Bryjak M, and Yuksel M. Removal of Boron from aqueous solutions by a hybrid ion exchange–membrane process. Desalination, 2006; 198(1-3): 158-165. DOI: 10.1016/j.desal.2006.09.011
2. Bhagyaraj S, Al-Ghouti MA, Kasak P, and Krupa I. An updated review on boron removal from water through adsorption processes. emerg mater. 2021; 4: 1167-1186 . DOI: 10.1007/s42247-021-00197-3
3. Hughes MF. Arsenic toxicity and potential me-chanisms of action. Toxicol Lett. 2002; 133(1): 1-16. DOI: 10.1016/S0378-4274(02)00084-X
4. Cervilla LM, Rosales MA, Rubio-Wilhelmi MM, Sanchez-Rodrı´guez E, Blasco B, Rı´os JJ, Romero L, and Ruiz JM. Involvement of lignification and membrane permeability in the tomato root response to boron toxicity. Plant Sci. 2009; 176(4): 545-552. DOI: 10.1016/j.plantsci.2009.01.008
5. World Health Organization (WHO). Background document for development of WHO guidelines for drinking-water quality. Boron in drinking-water. 2003. Available at: https://apps.who.int/iris/bitstream/handle/10665/70170/WHO_HSE_WSH_09.01_2_eng.pdf?sequence=1&isAllowed=y
6. Hydromantis Inc, Minnow Environmental Inc, and university of Waterloo. Review of the state of knowledge of municipal effluent science and research – review of effluent substances. Report prepared for: Development committee for the MWWE Canada-wide Sstrategy Canadian council of ministers of the environment; 2005. Available at: https://www.pseau.org/outils/ouvrages/ccme_review_of_the_state_of_knowledge_of_municipal_effluent_science_and_research_2005.pdf
7. Schuler CA. Impacts of agricultural drainwater and contaminants on wetlands at Kesterson Reservoir, California. M.Sc. Thesis, Oregon State University, Corvallis; 1987. 136 pp. Available at: Available at: https://b2n.ir/d38345
8. Srinath T, Verma TP, Ramteke W, and Garg SK. Chromium (VI) biosorption and bioaccumulation by chromate resistant bacteria. Chemosphere. 2002; 48(4): 427-435. DOI: 10.1016/S0045-6535(02)00089-9
9. Nirmal Kumar JI, Oommen C, and Kumar RN. Biosorption of heavy metals from aqueous solution by green marine macroalgae from Okha Port, Gulf of Kutch, India. Am-Eurasian J Agric Environ Sci, 2009; 6(3): 317-323. Available at: https://www.cabdirect.org/cabdirect/abstract/20103030131
10. Abbasi A, Yahya WZN, Nasef MM, Moniruzzaman M, Ghumman ASM, and Afolabi HK. Boron removal by glucamine-functionalized inverse vulcanized sulfur polymer. React Funct Polym. 2022; Available at: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85132324642&doi=10.1016%2fj.reactfunctpolym.2022.105311&partnerID=40&md5=b2f26103120cba7136449455759b9d96
11. Noori M, Zakeri R, Mazaheri SA, Gharaie M, and Mahmudy Gharaie MH. Studies of water arsenic and boron pollutants and algae phytoremediation in three springs, Iran. Int J Eco. 2012; 2(3): 32-37. Available at: http://article.sapub.org/10.5923.j.ije.20120203.01.html
12. Giese EC, Silva DDV, Costa AFM, Almeida SGC, and Dussán KJ. Immobilized microbial nanoparticles for biosorption. Crit Rev Biotechnol. 2020; 40(5): 653-666. Doi: 10.1080/07388551.2020.1751583
13. Cai XH, Logan T, Gustafson T, Traina S, and Sayre RT. Heavy metal binding properties of wild type and transgenic algae (Chlamydomonas sp.). In: Gal YL, Halvorson HO, editors. New developments in marine biotechnology., Boston, MA: Springer; 1998. pp. 189-192. DOI: 10.1007/978-1-4757-5983-9_39
14. Ankit, Bauddh K, and Korstad J. Phycoremediation: Use of algae to sequester heavy metals. Hydrobiology. 2022; 1(3): 288-303. DOI: 10.3390/hydrobiology1030021
15. Baker AJM. Accumulators and excluders- strategies in the response of plants to heavy metals, J Plant Nutr. 1981; 3(1-4): 643-654. DOI: https://doi.org/10.1080/01904168109362867
16. Nidhin S, Udayan A, and Srinivasan S. Algal bioremediation of heavy metals: Removal of toxic pollutants through microbiological and tertiary treatment. Elsevier; 2020. p. 279-307. DOI: 10.1016/B978-0-12-821014-7.00011-3
17. Bauddh K and Korstad J. Phycoremediation: Use of Algae to Sequester Heavy Metals. Hydrobiology, 2022; 1(3); 288-303.
18. Li S, Huang J, Liu H, Zhang Y, Ye X, Zhang H, et al. Adsorption of boron by CA@ KH-550@ EPH@ NMDG (CKEN) with biomass carbonaceous aerogels as substrate. J Hazard Mater . 2018; 358: 10-19. DOI: 10.1016/j.jhazmat.2018.06.040
19. Elsayed SA, Saad EM, Butler IS, and Mostafa SI. 2-Hydroxynaphthaldehyde chitosan schiff-base; new complexes, biosorbent to remove cadmium (II) ions from aqueous media and aquatic ecotoxicity against green alga Pseudokirchneriella subcapitata. J Environ Chem Eng. 2018; 6(2): 3451-3468. Available at: https://www.cabdirect.org/cabdirect/abstract/20193306400
20. [20]. Leliaert F, Smith DR, Moreau H, Herron MD, Verbruggen H, Delwiche CF, et al. Phylogeny and molecular evolution of the green algae, Crit Rev Plant Sci. 2012; 31(1): 1-46. DOI: 10.1080/07352689.2011.615705
21. Aliya NK, Jijeesh CM, and Jisha KC. Algae: Source of biofuel and phytoremediation. Bioenergy Crops. 2022; 112-135. Available at: https://www.taylorfrancis.com/chapters/edit/10.1201/9781003043522-6/algae-source-biofuel-phytoremediation-aliya-jijeesh-jisha
22. da Costa TB, da Silva TL, Dias Costa CS, da Silva MGC, and Vieira MGA. Chromium adsorption using Sargassum filipendula algae waste from alginate extraction: Batch and fixed-bed column studies. Adv Chem Eng. 2022; 11: 100341. DOI: 10.1016/j.ceja.2022.100341
23. Chugh M, Kumar L, Shah MP, and Bharadvaja N. Algal bioremediation of heavy metals: An insight into removal mechanisms, recovery of by-products, challenges, and future opportunities. Energy Nexus. 2022; 7: 100129. DOI: 10.1016/j.nexus.2022.100129
24. Zhou T, Li X, Zhang Q, Dong S, Liu H, Liu Y, et al. Ecotoxicological response of Spirulina platensis to coexisted copper and zinc in anaerobic digestion effluent. Sci. Total Environ. 2022; 837:155874. Doi: 10.1016/j.scitotenv.2022.155874
25. Mofeed J. Biosorption of heavy metals from aqueous industrial effluent by non-living biomass of two marine green algae ulva lactuca and dunaliella salina as biosorpents. Catrina. 2017; 16(1): 43-52. Available at: https://cat.journals.ekb.eg/article_14267_44b45fccc21ef45e9b0210da0fac0265.pdf
26. Gupa VK, Shrivastava AK, and Neeraj J. Biosorption Chromium from aqueous solutions by green algae Spirogyra species. Water Res. 2001; 35(17): 4079-4085. Doi: 10.1016/S0043-1354(01)00138-5
27. Kumar Y, King P, and Prasad V. Removal of copper from aqueous solution using Ulva fasciata sp-a marine green algae. J of Hazardous Materials 2006; 137(1): 367-373. DOI: 10.1016/j.jhazmat.2006.02.010
28. Ahuja P, Gupta R, and Saxena RK. News & notes: Sorption and desorption of cobalt by Oscillatoria anguistissima. Curr Microbiol. 1999; 39: 49-52. Doi: 10.1007/PL00006826
29. Singh A, Mehta SK, and Gaur JP. Removal of heavy metals from aqueous solution by common freshwater filamentous algae. World J Microbiol Biotechnol. 2007; 23: 1115-1120. Doi: 10.1007/s11274-006-9341-z